Buffalo National River

Geologic Resources Division
National Park Service
US Department of the Interior

The Geologic Resource Evaluation (GRE) Program provides each of 270 identified natural area National Park Service units with a geologic scoping meeting, a digital geologic map, and a geologic resource evaluation report. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity for discussion of park-specific geologic management issues and, if possible, include a site visit with local experts. The purpose of these meetings is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and potential monitoring and research needs. Outcomes of this scoping process are a scoping summary (this report), a digital geologic map, and a geologic resource evaluation report.

The National Park Service held a GRE scoping meeting for Buffalo National River on April 25, 2007 at park headquarters in Harrison, Arkansas followed by a floating field trip from Tyson's Bend to Gilbert on April 26, 2007. Tim Connors (NPS-GRD) facilitated the discussion of map coverage and Bruce Heise (NPS-GRD) led the discussion regarding geologic processes and features at the national river. Participants at the meeting included NPS staff from the park, Geologic Resources Division, Arkansas Geological Survey, Cave Research Foundation, Missouri State University, University of Arkansas, and the U.S. Geological Survey as well as cooperators from Colorado State University (see table 1). This scoping summary highlights the GRE scoping meeting for Buffalo National River including the geologic setting, the plan for providing a digital geologic map, a prioritized list of geologic resource management issues, a description of significant geologic features and processes, lists of recommendations and action items, and a record of meeting participants.

Park and Geologic Setting

Buffalo National River preserves one of the few remaining unpolluted, free-flowing rivers in the conterminous United States. Congress authorized this unit on March 1, 1972, and the national river received a wilderness designation (3 units) on November 10, 1978. Along its 218.47-km length (135.75-mile), the unit covers some 94,293.31 acres (Federal: 91,813.09 acres, wilderness: 36,000 acres). The park extends in a narrow tract from the Upper Buffalo Wilderness area roughly northeastward to the confluence with the White River at Buffalo City. The park sits within or just adjacent to 18 7.5-minute quadrangles. Larger tributaries to the Buffalo River include Middle, Big, Clabber, Water, Tomahawk, Brush, Bear, Calf, Richland, Davis, Mill, Cave, Cove, and Wells Creeks in addition to the Little Buffalo River. The river cuts a winding course through gently undulating, relatively undeformed geologic units ranging in age from Silurian to Pennsylvanian. Geologic structures include the Mill Creek Graben, monoclinal folds, relatively small-scale strike-slip and normal faults, and joint sets. Mixed limestone, siltstone, sandstone, and shale deposited in the Paleozoic Arkoma basin now form a series of eroded plateaus in northern Arkansas. Resistant sandstones and cherts cap the higher knobs and ridges. The limestone-rich units such as the Boone, Everton and Bloyd Formations are susceptible to karstification. Many springs, pits, sinks, and caves are present in the park. Steep cliffs, bluffs, and ledges cut by small tributary valleys alternating with broad point bar alluvial deposits characterize the river corridor.

Geologic Mapping for Buffalo National River

During the scoping meeting Tim Connors (NPS-GRD) showed some of the main features of the GRE Programs digital geologic maps, which reproduce all aspects of paper maps, including notes, the legend, and cross sections, with the added benefit of GIS compatibility. The NPS GRE Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation set for the GRE Program. Staff members digitize maps or convert digital data to the GRE digital geologic map model using ESRI ArcMap software. Final digital geologic map products include data in geodatabase, shapefile, and coverage format, layer files, FGDC-compliant metadata, and a Windows HelpFile that captures ancillary map data. Completed digital maps are available from the NPS Data Store at http://science.nature.nps.gov/nrdata/.

When possible, the GRE program provides large scale (1:24,000) digital geologic map coverage for each park's area of interest, usually composed of the 7.5-minute quadrangles that contain park lands (figure 1). Maps of this scale (and larger) are useful to resource management because they capture most geologic features of interest and are positionally accurate within 40 feet. The process of selecting maps for management use begins with the identification of existing geologic maps and mapping needs in vicinity of the park. Scoping session participants then select appropriate source maps for the digital geologic data to be derived by GRE staff as well as determine areas in need of further mapping or refinement. Table 2 (at the end of this document) lists the source maps chosen for Buffalo National River as well as any further action required to make these maps appropriate for inclusion.

Buffalo National River expressed interest in obtaining map coverage for their entire watershed (both to the north and to the south). There were initially 38 7.5' quadrangles of interest from the NPS QOI database as follows: Norfork, Buffalo City, Rea Valley, Yellville, Harrison, Gaither, Osage NE, Norfork SE, Big Flat, Cozahome, Maumee, St. Joe, Western Grove, Hasty, Jasper, Ponca, Osage SW, Landis, Harriet, Marshall, Snowball, Eula, Mount Judea, Parthenon, Murray, Boxley, Weathers, Oxley, Canaan, Witts Springs, Moore, Lurton, Deer, Swain, Fallsville, Boston, Smyrna, and Sand Gap. The Tilly 7.5' quadrangle (just south of Witts Spring and east of Smyrna) shows on the shapefile provided by BUFF staff, but is not in the QOI database, making for a total of 39 quadrangles intersecting the watershed.

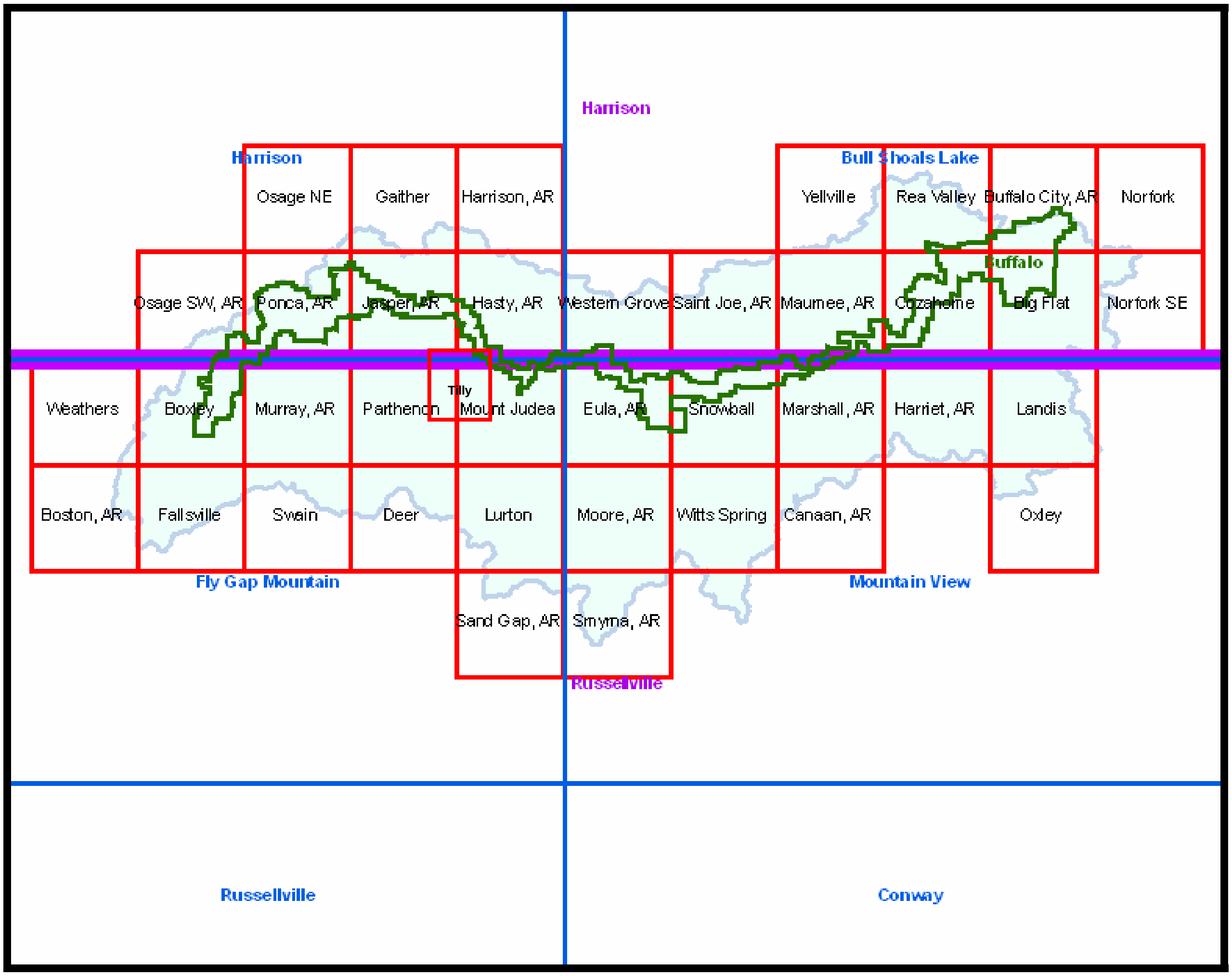

Figure 1. BUFF watershed (light blue), park boundary (green), and 7.5' quadrangles of interest (red), 30x60 (blue), 1x2 (purple)

At the present time, there is much dedicated large-scale 7.5' geologic mapping for the BUFF watershed, as well as a few data gaps. Where there is published, digital geology for the BUFF watershed, GRE staff will convert this information and supply to the park. Where there is no large-scale dedicated mapping, GRE will work with both the USGS and AR GS to best fill these areas.

The graphic below best illustrates the availability of published, digital geology for the BUFF area (combination of both USGS and AR GS publications).

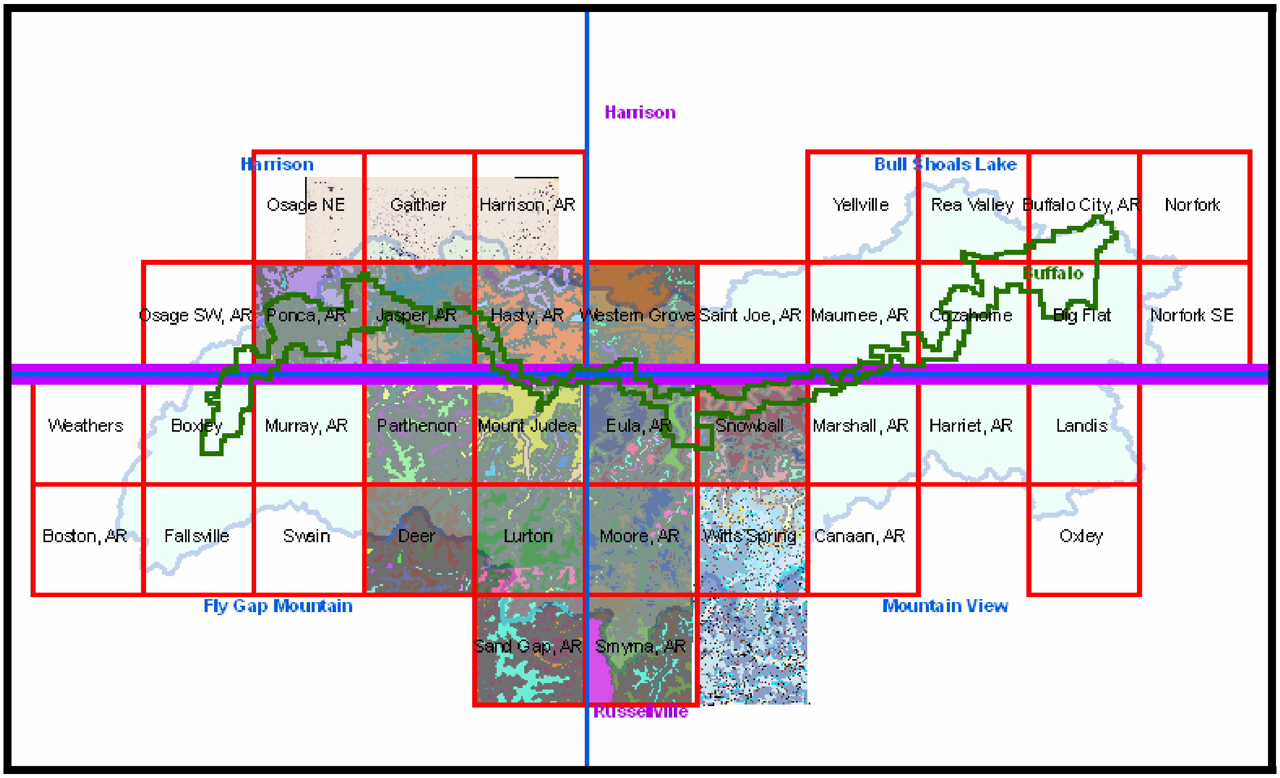

Figure 2. Published large-scale maps for BUFF area

For areas not shown to have published coverage, the following is what is known with regards to obtaining large-scale geologic map coverage:

- In the eastern part of the park, the AR GS has proposed to do 7.5’ geologic quadrangle mapping for the Buffalo City, Rea Valley, Big Flat, and Cozahome; this proposal is currently being worked out between the NPS (Bruce Heise) and AR GS (Bekki White).

- In the east-central part of the park, the USGS has been funded by the NPS-WRD (Pete Penoyer) to do 7.5’ geologic quadrangle mapping for the Saint Joe and Maumee as part of the Tomahawk Creek Basin study; Mark Hudson estimated 33% of the field mapping to be complete as of April 2007.

- In the western part of the park, the USGS is nearing finalization of the Boxley 7.5’ quadrangle (Mark Hudson says it is in USGS press as of April 2007). Additionally Hudson has proposals to do both the Murray and Osage SW quadrangles, but nothing firmer.

- In the southeast part of the park and part of the watershed, the AR GS began quadrangle mapping for the Marshall, Harriett and Landis, which they plan to publish by June 30, 2008

Mapping needs persist for the watershed (not quadrangles intersecting the park) for the following quadrangles: Norfolk, Yellville, Osage NE, Norfolk SE, Weathers, Oxley, Canaan, Swain, Fallsville, and Boston.

Please note, that the Harrison 1x2 (GMAP 1475; Middendorf, M.A., Thompson, K.C., Robertson, C.E., Whitfield, J.W., Glick, E.E., Bush, W.V., Haley, B.R., and McFarland, J.D., 1997, Geologic map of the Harrison 1 degree X 2 degree quadrangle, Missouri and Arkansas, , Miscellaneous Geologic Investigations Map I-2548, 1:250,000 scale) does give coverage at small-scale for the Norfolk, Yellville, Osage NE, and Norfolk SE quadrangles.

Table 2 lists the source maps chosen for Buffalo National River and mapping needs in certain quadrangles, in addition to a unique "GMAP ID" number assigned to each map by GRE staff for data management purposes, map scale, and action items.

Additional items of interest pertaining to geologic mapping from the scoping

The site has interest in groundwater flow maps, watershed delineation, using detailed terrace analysis and mapping to determine the incision history of the river, additional fault mapping, cave and karst feature mapping, landscape evolution maps, and mapping landslide areas.

Geologic Resource Management Issues

The scoping session for Buffalo National River provided the opportunity to develop a list of geologic features and processes, which will be further explained in the final GRE report. During the meeting, participants prioritized the most significant issues as follows:
(1) Fluvial issues
(2) Cave and karst issues
(3) Mass wasting
(4) Disturbed lands and adjacent land use
(5) Paleontological resources

Fluvial Issues

The Buffalo River is the primary natural resource at the park. Fluvial issues include riverbank and head-cutting erosion as well as increased sedimentation forming braided channels in some areas. The inherent steepness of the river course leads to high-energy instability along its corridor. Sediment input (sand and gravel) along the river increases due to adjacent deforestation and other landuse activities. Horse and human trail crossings cause localized erosion problems.

Fluvial terraces along the river contain an important record of fluvial processes and stream incision with implications for cave evolution and paleoclimate research. The first widely identified terrace occurs at 9 to 15 m (30-50 ft) above the river. The second terrace is 6 m (20 ft) above the first and the third terrace is much higher and less recognizable.

During peak flows and flood events, the river can rise 20 m (60 ft) above normal levels. This level of flooding occurs on a 50-65-year recurrence interval. In 1982, a flood event covered one of the larger bridges crossing the river. The Buffalo River becomes a sinking stream during seasonal low flow. At Horseshoe Bend, the river disappears along a structure controlled by a fault in the lower Everton Formation. At two other localities (Boxley Valley and Woolum), the river disappears into karst conduits within the Mississippian Boone Formation.

Efforts to engineer the river corridor or stabilize shorelines include rip rap, some channelization (formerly by bulldozers), short-term cedar tree revetments, and rock vanes to protect canoe launch sites. The upper Buffalo corridor of federal land is managed with a scenic easement on private lands. The park wants to keep the river flowing through the federal corridor and not encroach on adjacent agricultural lands. In floodplain areas, river migration can be aggressive during high flow events. At Woolum, riprap protects a park road and cedar revetments are in place to maintain the current shoreline.

Caves and Karst Issues

Karst processes are active on the landscape at Buffalo National River. Karstification involves the processes of chemical erosion and weathering of limestone or dolomite (carbonate rocks) (Palmer, 1981). Dissolution occurs when acidic water reacts with carbonate rock surfaces along cracks and fractures. At Buffalo River, karst dissolution occurs in every unit that contains carbonate or carbonate cemented sandstone. Karst features include caves, conduits, pits, sinks, alcoves, karst aquifers, springs, and paleokarst. Approximately 360 cave openings occur in the park including the largest known cave in Arkansas – Fitton Cave at 24 km (15 miles) long. Erosion and dissolution form large sandstone overhangs that create bluff shelters. These shelters may contain archaeological resources.

The Cave Research Foundation mapped Fitton Cave including cave passage locations and 6 different levels all overlain onto a geologic and topographic base. The passages of Fitton Cave reveal it short-circuited streams at different levels in the past. Further cave mapping and digitization of legacy products is a significant resource management need at Buffalo River.

In the Buffalo River area, the groundwater watershed does not correspond with the surficial drainage basin divides. Groundwater flows from other basins (possibly Crooked Creek among others) into the Buffalo River basin, emerging as springs. Dog Patch Spring flows beneath a surficial divide. A topographic low and a fault surface control the flow in this system. The Boone Formation includes a perched aquifer above the river. The Everton Formation acts as a regional aquitard. In addition to karstification, geologic structures control spring location. In some areas upper level springs concentrate at structural lows whereas lower springs concentrate at highs where hydraulic pressure forces water to the surface.

According to Mark Hudson (USGS), along certain stretches of the river, nearly 75% of known cave openings occur in the Mississippian-age Boone Formation, about 20% of openings are in the Everton Formation, and less than 10% are in the lower Bloyd Formation. Spring horizons seem to correlate with the bases of these units as well.

Caves are at risk of vandalism, archaeological looting, and speleothem theft at Buffalo River. Other hazards related with karst features include sinkhole development, and steep pits dropping hundreds of feet that are difficult to see at the surface. The park wants to keep cave locations free of gates and fences and protect the natural environment and habitat the caves provide. To this end, the park wants to keep visitors away from cave resources at Buffalo National River. Cave locations and maps are sensitive data.

Mass Wasting

Buffalo River cuts through steep slopes, terraces, bluffs, and alluvial fans. Gravity, frost and plant root wedging, erosion, and karst dissolution are primary causes of slope instability. As such, hillslope processes such as landslides and rockfall are prevalent issues at the park. Certain geologic units such as the Fayetteville Shale act as regional slip surfaces and are present at the toe of most slides. The park also contains torevas (stratified tilted blocks of Ordovician or Upper Mississippian and Pennsylvanian units) that slide as a semi-coherent unit. Upon further sliding, the toreva becomes a jumbled earthflow. Other units such as the Boone Formation are prone to karst dissolution, sinkhole collapse, and rockfall along the riverway. This unit contains large, resistant deposits of chert that when undercut, pose a serious rockfall hazard. At “The Barns” following a drought period which reduced stabilizing vegetation, a precipitation event widened cracks by swelling clays causing a bus-sized block of the Boone Formation to fail. Colluvial fans occur at the base of many slopes and bluffs along the river. Ancient rockfalls and slides left scars along the slopes of the river valley.

There are questions surrounding the mass wasting processes along park slopes including how they formed and how active they are at present. Some park infrastructure is threatened by mass wasting events including Boxley Valley and roads at Jasper (Hwy. 21). Any steep slope at the park poses a landslide hazard and rockfall is a threat along long stretches of the river. Visitors should be made aware of rockfall potential and warned about active slide and rockfall areas.

Disturbed Lands and Adjacent Land Use

Coincident with the Ouachitan orogenic event in the Late Paleozoic, brine fluids flushed through the rocks to mineralize heavy metal deposits particularly along faults and other fractures. Major mining districts such as the Rolla district in Missouri extract heavy metal deposits from these features and share similar geologic structures with the Buffalo River area. The nearby lead and zinc Rush mining district (Rea Valley, Buffalo City, Big Flat quadrangles) overlaps with park land. Other mining operations include the Ponca lead mines, the Mt, Hersey area mines, and Dog Patch mines. Most mining interest in the area was over by World War II. These abandoned mines are bat habitat now. The park owns all mineral interests except for five tracts; however, no valid claims exist in park boundaries. Quarries and gravel pits exist within park boundaries. These provided aggregate for roadway construction.

Some active quarrying for sand, gravel, and clay is ongoing near the park for local construction, but at this time is of little concern to park management. Arkansas state highway requirements include 40% silica in road surface aggregate. The Department of Transportation may target chert deposits in the Buffalo River tributaries to supply the necessary silica content. Disturbances along these tributaries would increase sedimentation into the Buffalo River.

The Fayetteville Shale contains a high organic content, which companies elsewhere drill for natural gas plays. In the Buffalo River area, the shale is exposed, thus there is no potential for hydrocarbon extraction. Surrounding areas may be of some interest to oil and gas development in the future.

The park still permits cattle grazing in some areas with only 1-2 permits remaining. Adjacent logging activities have increased sedimentation into the Buffalo River and affect the viewshed. Abandoned access roads associated with logging, mining, and other activities are targets for reclamation. The park has some interest in restoring these areas to their natural condition.

As population increases, especially in the Harrison area, the park is concerned about negative impacts on its natural resources. There are very few regulations on housing/urban development in the Buffalo River area. Development is likely to focus on the northern and western sides of the park over the next 10-12 years. Highway 12 may soon be a 4-lane transportation corridor. Impermeable surfaces such as roads, parking lots, and driveways will increase. Potential negative effects range from overuse of the park's facilities and increased erosion and sediment load to water contamination and increased surface runoff. Karst-influenced aquifer systems are especially vulnerable to contamination because any input is quickly transferred through the system with little if any natural filtering or sorption (Ryan and Meiman, 1996).

Paleontological Resources

The few significant fossil localities at Buffalo River have yet to be comprehensively studied or inventoried. The Mississippian Boone Formation contains crinoids, shark teeth, and invertebrates. Pennsylvanian age rocks contain abundant plant fossil remains, trace fossils and tree casts. Brachiopod casts are in the Wedington and Batesville units. Scant ostracodes exist in the Ordovician units. Trilobites are in the older Silurian units (St. Clair Formation) in the park area. The Pitkin Formation contains diverse fauna including interesting Archimedes bryozoans.

An unusual deposit of Pleistocene fossils sits just outside park boundaries at the Conard fissure. This geologic structure (karst trap – collapsed sinkhole) provided a small trap for vertebrate fossil remains off the Buffalo River. The potential exists for other such traps in notches and caves throughout the park. Several caves in the park contain mammoth, mastodon and cave bear bones, some of which have been lost to theft.

Features and Processes

Karst processes are a major geomorphologic force on the landscape at Buffalo National River. Because erosion has removed insoluble rocks such as sandstones, siltstones, and shales from limestone-rich soluble layers, erosion and dissolution are pervasive. Insoluble rocks cap nearby topographically high areas such as Cleveland Knob, Spencer Ridge, Prince Fred Knob, Rose Ridge, Gobblers Knob, Point Peter Mountain, Pleasant Hill, and Lead Hill among many others. The landscape at Buffalo National River is a testament to fluvial erosion in addition to active karst processes of limestone dissolution, underground cavity development, spring activity, and sinkhole collapse. Interesting paleokarst (cemented breccias filling large cavities) formed long ago by collapse of overlying sandstones into limestone rich layers of the lower Everton Formation. At Mitch Hill, dye traces revealed an uncommon karst window bringing up a lower spring.

Type sections refer to the originally described sequence of strata that constitute a geologic unit. It serves as an objective standard for comparison with spatially separated parts of that same unit. Preferably, a type section describes an exposure in an area of maximum unit thickness and completeness. There are excellent quality exposures of the Boone Formation in the park. Boone County leant its name to this unit and exposures in the area provide a broad type section. The St. Joe quadrangle lent its name to the St. Joe Limestone. It is unknown where if any specific exposure is the type section. Most type sections for the geologic units present at Buffalo River are in the Fayetteville area.

Recommendations

(1) Perform further groundwater dye trace studies to understand the flow of groundwater in the park and delineate the subterranean watershed. Focus on the Water Creek basin next. NPS-WRD is a potential partner in this project.
(2) Promote a potential Master's thesis project to obtain sediment samples looking for lead and zinc mineralization along the river corridor.
(3) Perform a comprehensive paleontological inventory of the national river. Establish a plan to deal with potential illegal sampling and collecting.
(4) Research the incision history of the river using distinguishable, dated terrace deposits, and the relationship with cave formations and faulting.
(5) Cooperate with the Cave Research Foundation and other agencies to perform comprehensive cave mapping at Buffalo River. Incorporate cave maps and locations into park's GIS.
(6) Locate all vertebrate paleontological resources in pits and caves along the river. Caves with drops commonly contain these types of remains.
(7) Perform sedimentation and palynologic studies on largely undisturbed cave deposits and other sediments

(8) Investigate the potential for speleothems to contain a record of paleoclimate in the region.
(9) Vast potential remains to further refine the overall tectonic history of the region as the river exposes rocks that are elsewhere covered and/or overgrown including understanding the relationships between structure, stratigraphy, lead/zinc mineralization (dates in fluid inclusions), chert geochemistry, etc., as well as the fluvial geomorphology, and mass wasting history in the park through careful mapping and stratigraphic studies.
(10) Compare surficial and cave fracture orientations. Also note local gradients and proximities of caves to streams.
(11) Perform hydrogeologic modeling to determine the mechanics of the karst window and lower spring at Mitch Hill.

Action Items

(1) GRE staff will discuss promoting cave inventory with NPS-GRD.
(2) GRE will produce digital geologic map for the national river (see above geologic mapping section).
(3) Park should obtain results from heavy metal sampling in the area by the Arkansas Geological Survey.
(4) GRE report author needs to obtain 1935 stratigraphic paper by McKnight, a *Geology* paper by M. Hudson (2000), and the USGS Folio report for the geology of the area (ca. 1895).
(5) GRD will contact Vince Santucci (NPS-GWMP) regarding a possible paleontological inventory for the river.

References

www.nps.gov/buff (accessed May 3, 2007)

www.topozone.com (accessed May 4, 2007)

Palmer, A.N. 1981. *A geological guide to Mammoth Cave National Park*. Teaneck, NJ: Zephyrus Press.

Ryan, M., Joe Meiman. 1996. An examination of a short-term variations in water quality at a karst spring in Kentucky. *Ground Water* 34 (1): 23-30.

Table 1. Scoping Meeting Participants

Name	Affiliation	Position	Phone	E-Mail
Ausbrooks, Scott	Arkansas Geological Survey	Geologist	501-683-0119	Scott.ausbrooks@arkansas.gov
Bitting, Chuck	NPS-BUFF	Geologist	870-741-5446	Chuck_bitting@nps.gov
Brahana, Van	University of Arkansas	Geologist	479-575-2570	brahana@uark.edu
Chandler, Angela	Arkansas Geological Survey	Geologist	501-683-0114	angela.chandler@arkansas.gov
Connors, Tim	NPS – GRD	Geologist	303-969-2093	Tim_Connors@nps.gov
Croskrey, Andrea	NPS – GRD	Geologist	303-969-2148	Andrea_croskrey@nps.gov
De Poy, Mark	NPS-BUFF	Natural Resources	870-741-5446 ext. 270	Mark_depoy@nps.gov
Gouzie, Doug	Missouri State University	Geologist	417-836-5228	douglasgouzie@missouristate.edu
Heise, Bruce	NPS – GRD	Geologist	303-969-2017	Bruce_Heise@nps.gov
House, Scott	Cave Research Foundation	President	573-651-3782	Scott_house@semo.net
Hudson, Mark	US Geological Survey	Geologist	303-236-7446	mhudson@usgs.gov
Thornberry-Ehrlich, Trista	Colorado State University	Geologist-Report Writer	757-416-5928	tthorn@cnr.colostate.edu
White, Bekki	Arkansas Geological Survey	State Geologist	501-296-1880	bekki.white@arkansas.gov

Table 2. GRE Mapping Plan for Buffalo National River[1] *(beginning in northeast quadrangles and proceeding west, then south)*

7.5' Quadrangle Level of interest (Intersects park or Watershed)	GMAP ID	Best Known available reference	GRE appraisal URL (if applicable)	GRE Action	Scale
Norfork **(WATERSHED)**	1475	Middendorf, M.A., Thompson, K.C., Robertson, C.E., Whitfield, J.W., Glick, E.E., Bush, W.V., Haley, B.R., and McFarland, J.D., 1997, Geologic map of the Harrison 1 degree X 2 degree quadrangle, Missouri and Arkansas, , Miscellaneous Geologic Investigations Map I-2548, 1:250000 scale	No large-scale known mapping; quadrangle in BUFF watershed but just barely and doesn't intersect park, so GRE not likely to fund new mapping in this area at this time. Use GMAP 1475 if data necessary; would likely have to digitize as not known to be digital	***GRE not likely to fund new mapping***	250000
Buffalo City **(PARK)**	74674	Arkansas Geological Survey staff, 2007, Unpublished Geologic Map of the Buffalo City Quadrangle, Arkansas, Arkansas Geological Survey , unpublished, 1:24000 scale	2007-0730: GRE working with ARGS for mechanism to get this mapped; have received scans of preliminary field sheets from ARGS; GRE would convert on delivery	Work with AR GS to get mapped; await digital data; when published convert to NPS GRE data model	24000
Rea Valley **(PARK)**	74687	Arkansas Geological Survey staff, 2007, Unpublished Geologic Map of the Rea Valley 7.5' Quadrangle, Arkansas, , Arkansas Geological Survey, unpublished, 1:24000 scale			24000
Yellville **(WATERSHED)**	1475	Middendorf, M.A., Thompson, K.C., Robertson, C.E., Whitfield, J.W., Glick, E.E., Bush, W.V., Haley, B.R., and McFarland, J.D., 1997, Geologic map of the Harrison 1 degree X 2 degree quadrangle, Missouri and Arkansas, , Miscellaneous Geologic Investigations Map I-2548, 1:250000 scale	No large-scale known mapping; quadrangle in BUFF watershed but only small portion in southeast corner and doesn't intersect park, so GRE not likely to fund new mapping in this area at this time. Use GMAP 1475 if data necessary; would likely have to digitize as not known to be digital	***GRE not likely to fund new mapping***	250000
Harrison & Gaither **(WATERSHED)**	1474	Hudson, M.R., 1998, Geologic map of parts of the Gaither, Hasty, Harrison, Jasper and Ponca quadrangles, Boone and Newton Counties, northern Arkansas, , Open-File Report OF-98-116, 1:24000 scale	2007-0730: should be superceded by dedicated 7.5' quadrangles for Hasty (GMAP 68982), Jasper (GMAP 3807) and Ponca (GMAP 4854), but not known to be superceded for Gaither and Harrison (which are both BUFF watershed QOIs). For the Gaither & Harrison 7.5's, this doesn't cover the full quadrangles, but should cover enough of BUFF watershed of interest area to be of utility for GRE. Don't have any digital files from USGS website either, so would need to either digitize or try to get from Mark Hudson (USGS)	GRE obtain digital files from USGS for conversion	24000
Osage NE	1475	Middendorf, M.A., Thompson, K.C., Robertson, C.E.,	No large-scale known mapping; quadrangle in BUFF	***GRE not likely to***	250000

[1] Yellow highlighting denotes "unpublished" geologic mapping yet to be conducted or delivered; green highlighting denotes published geologic mapping that has digital GIS supporting data; no highlighting denotes no known dedicated large-scale 7.5' mapping available or currently proposed

7.5' Quadrangle Level of interest (Intersects park or Watershed)	GMAP ID	Best Known available reference	GRE appraisal URL (if applicable)	GRE Action	Scale
(WATERSHED) Norfork SE (WATERSHED)		Whitfield, J.W., Glick, E.E., Bush, W.V., Haley, B.R., and McFarland, J.D., 1997, Geologic map of the Harrison 1 degree X 2 degree quadrangle, Missouri and Arkansas, , Miscellaneous Geologic Investigations Map I-2548, 1:250000 scale	watershed but just barely and doesn't intersect park, so GRE not likely to fund new mapping in this area at this time. Use GMAP 1475 if data necessary; would likely have to digitize as not known to be digital	***fund new mapping***	
Big Flat (PARK)	74688	Arkansas Geological Survey staff, 2007, Unpublished Geologic Map of the Big Flat Quadrangle,, Arkansas, , unpublished, 1:24000 scale	2007-0730: GRE working with ARGS for mechanism to get this mapped; have received scans of preliminary field sheets from ARGS; GRE would convert on delivery	Obtain digital data when published and convert to NPS GRE data model	24000
Cozahome (PARK)	74675	Arkansas Geological Survey staff, 2007, Unpublished Geologic Map of the Cozahome Quadrangle, Arkansas, , unpublished, 1:24000 scale			24000
Maumee (PARK)	74689	Hudson, Mark, 2007, Unpublished Geologic Map of the Maumee Quadrangle,, Arkansas, , unpublished, 1:24000 scale	2007-0730: USGS currently mapping; ~33% field mapped; GRE will convert upon delivery		24000
St. Joe (WATERSHED)	NA	Hudson, Mark, 2007, Unpublished Geologic map of the Saint Joe 7.5' Quadrangle, --- Counties, Arkansas, , unpublished, 1:24000 scale			24000
Western Grove (PARK)	74478	Hudson, M.R., Turner, K.J., Repetski, J.E., 2006, Geologic map of the Western Grove quadrangle, northwestern Arkansas. U.S. Geological Survey, Scientific Investigations Map SIM-2921	http://pubs.usgs.gov/sim/2006/2921/	Obtain digital data from USGS websites and convert to NPS GRE data model	24000
Hasty (PARK)	68982	Hudson, M.R., Murray, K.E., 2004, Geologic map of the Hasty quadrangle, Boone and Newton Counties, Arkansas. U.S. Geological Survey Scientific Investigations Map SIM-2847	http://pubs.usgs.gov/sim/2004/2847/		24000
Jasper (PARK)	3807	Hudson, M.R., Murray, K.E., Pezzutti, D., 2001, Geologic map of the Jasper quadrangle, Newton and Boone Counties, Arkansas. U.S. Geological Survey MF-2356	http://pubs.usgs.gov/mf/2001/mf-2356/		24000
Ponca (PARK)	4854	Hudson, M.R., Murray, K.E., 2003, Geologic map of the Ponca quadrangle, Newton, Boone, and Carroll Counties, Arkansas. U.S. Geological Survey MF-2412	http://pubs.usgs.gov/mf/2003/mf-2412/		24000
Osage SW (PARK)	1475	Middendorf, M.A., Thompson, K.C., Robertson, C.E., Whitfield, J.W., Glick, E.E., Bush, W.V., Haley, B.R., and McFarland, J.D., 1997, Geologic map of the Harrison 1 degree X 2 degree quadrangle, Missouri and Arkansas, , Miscellaneous Geologic Investigations Map I-2548, 1:250000 scale	2007-0731: USGS (Mark Hudson) is proposing to map Osage SW & Murray after completion of Boxley, but nothing firm at this point in time	Obtain digital data when published and convert to NPS GRE data model	250000

7.5' Quadrangle Level of interest (Intersects park or Watershed)	GMAP ID	Best Known available reference	GRE appraisal URL (if applicable)	GRE Action	Scale
Landis **(WATERSHED)**	74774	Arkansas Geological Survey staff, 2008, Unpublished Geologic map of the Landis 7.5' Quadrangle, --- Counties, Arkansas, , unpublished, 1:24000 scale	2007-0730: AR GS currently mapping and planning on completing by June 30, 2008. GRE will then convert files.	Obtain digital data when published and convert to NPS GRE data model	24000
Harriet **(WATERSHED)**	74775	Arkansas Geological Survey staff, 2008, Unpublished Geologic map of the Harriet 7.5' Quadrangle, --- Counties, Arkansas, , unpublished, 1:24000 scale			24000
Marshall **(PARK)**	74776	Arkansas Geological Survey staff, 2008, Unpublished Geologic map of the Marshall 7.5' Quadrangle, --- Counties, Arkansas, , unpublished, 1:24000 scale			24000
Snowball **(PARK)**	62287	Braden, A.K., Ausbrooks, S.M., 2003, Geologic Map of the Snowball Quadrangle, Searcy County, Arkansas. Arkansas Geological Survey, Digital Geologic Quadrangle Map DGM-AR-00800	2007-0730: intersecting BUFF QOI ; downloaded PDF from AGS website; also received GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/snowball.pdf	Have Obtained digital data from AGS and need to convert to NPS GRE data model	24000
Eula **(PARK)**	62271	Braden, A.K., Ausbrooks, S.M., 2003, Geologic Map of the Eula Quadrangle, Newton and Searcy Counties, Arkansas. Arkansas Geological Survey, Digital Geologic Quadrangle Map DGM-AR-00269	2007-0730: intersecting BUFF QOI ; downloaded PDF from AGS website; also received GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/eula.pdf		24000
Mount Judea **(PARK)**	60913	Braden, A.K., Ausbrooks, S.M., 2003, Geologic Map of the Mount Judea Quadrangle, Newton County, Arkansas. Arkansas Geological Survey, Digital Geologic Quadrangle Map DGM-AR-00590	2007-0730: intersecting BUFF QOI ; downloaded PDF from AGS website; also received GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/Mt.Judea.pdf		24000
Parthenon **(WATERSHED)**	4176	Braden, A.K., Ausbrooks, S.M., 2002, Geologic Map of the Parthenon Quadrangle, Newton County, Arkansas. Arkansas Geological Survey, Digital Geologic Quadrangle Map DGM-AR-00680	2007-0730: intersecting BUFF QOI ; downloaded PDF from AGS website; also received GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/Parthenon.pdf		24000
Murray **(PARK)**	NA	2007-0731: USGS (Mark Hudson) is proposing to map Osage SW & Murray after completion of Boxley, but nothing firm at this point in time		Obtain digital data when published and convert to NPS GRE data model	24000
Boxley **(PARK)**	74773	Hudson, Mark, 2007, Unpublished Geologic map of the Boxley 7.5' Quadrangle, --- Counties, Arkansas, , unpublished, 1:24000 scale	2007-0730: BUFF intersecting QOI; USGS currently in press; GRE will convert upon delivery	Obtain digital data when published and convert to NPS GRE datamodel	24000

7.5' Quadrangle Level of interest (Intersects park or Watershed)	GMAP ID	Best Known available reference	GRE appraisal URL (if applicable)	GRE Action	Scale
Weathers Oxley Canaan **(WATERSHED)**	NA	No large-scale known mapping; all three quadrangles in BUFF watershed, but don't intersect park, so GRE not likely to fund new mapping in these areas at this time		***GRE not likely to fund new mapping***	24000
Witts Spring **(WATERSHED)**	74770	Smith, D.K. and Hutto, R.S., 2007, Geologic map of the Witts Springs Quadrangle, Searcy County, Arkansas, , Digital Geologic Quadrangle Map DGM-AR-00927, 1:24000 scale	2007-0730: non-intersecting BUFF QOI, but is for watershed ; downloaded PDF from AGS website; need to request GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/wittsspring.pdf	Obtain digital data from AR GS and convert to NPS GRE data model	24000
Moore **(WATERSHED)**	74682	Braden, A.K., Smith, J.M., 2004, Geologic Map of the Moore Quadrangle, Newton and Searcy Counties, Arkansas. Arkansas Geological Survey, Digital Geologic Quadrangle Map DGM-AR-00579	2007-0730: non-intersecting BUFF QOI, but is for watershed ; downloaded PDF from AGS website; also have GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/moore.pdf		24000
Lurton **(WATERSHED)**	74683	Braden, A.K., Smith, J.M., 2004, Geologic Map of the Lurton Quadrangle, Newton County, Arkansas. Arkansas Geological Survey, Digital Geologic Quadrangle Map DGM-AR-00509	2007-0730: non-intersecting BUFF QOI, but is for watershed ; downloaded PDF from AGS website; also have GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/lurton.pdf		24000
Deer **(WATERSHED)**	74620	Braden, A.K., Smith, J.M., 2004, Geologic Map of the Deer Quadrangle, Newton County, Arkansas. Arkansas Geological Survey, Digital Geologic Quadrangle Map DGM-AR-00217	2007-0730: non-intersecting BUFF QOI, but is for watershed ; downloaded PDF from AGS website; also have GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/deer.pdf		24000
Swain Fallsville Boston **(WATERSHED)**	NA	No large-scale known mapping; all three quadrangles in BUFF watershed, but don't intersect park, so GRE not likely to fund new mapping in these areas at this time		***GRE not likely to fund new mapping***	24000
Tilly **(WATERSHED)**	74771	Smith, D.K. and Hutto, R.S., 2007, Geologic map of the Tilly Quadrangle, Searcy and Van Buren Counties, Arkansas, , Digital Geologic Quadrangle Map DGM-AR-00850, 1:24000 scale	2007-0730: non-intersecting BUFF QOI, but is for watershed ; downloaded PDF from AGS website; need to request GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/tilly.pdf	Obtain digital data from AR GS and convert to NPS GRE data model	24000

7.5' Quadrangle Level of interest (Intersects park or Watershed)	GMAP ID	Best Known available reference	GRE appraisal URL (if applicable)	GRE Action	Scale
Smyrna **(WATERSHED)**	74684	Braden, A.K., Smith, J.M., 2005, Geologic Map of the Smyrna Quadrangle, Newton, Searcy, and Pope Counties, Arkansas. Arkansas Geological Survey, Digital Geologic Quadrangle Map DGM-AR-00792	2007-0730: non-intersecting BUFF QOI, but is for watershed ; downloaded PDF from AGS website; need to request GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/smyrna.pdf		24000
Sand Gap **(WATERSHED)**	74685	Braden, A.K., Smith, J.M., 2005, Geologic Map of the Sand Gap Quadrangle, Newton and Pope Counties, Arkansas. Arkansas Geological Survey, Digital Geologic Quadrangle Map DGM-AR-00767	2007-0730: non-intersecting BUFF QOI, but is for watershed ; downloaded PDF from AGS website; need to request GIS files from Angela Chandler for GRE conversion http://www.state.ar.us/agc/sandgap.pdf		24000